

Unified approach to redshift in cosmological/black hole spacetimes and synchronous frame

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Abstract

© 2017 European Physical Society. Usually, interpretation of redshift in static spacetimes (for example, near black holes) is opposed to that in cosmology. In this methodological note, we show that both explanations are unified in a natural picture. This is achieved if, considering the static spacetime, one (i) makes a transition to a synchronous frame, and (ii) returns to the original frame by means of local Lorentz boost. To reach our goal, we consider a rather general class of spherically symmetric spacetimes. In doing so, we construct frames that generalize the well-known Lemaitre and Painlevé-Gullstrand ones and elucidate the relation between them. This helps us to understand, in a unifying approach, how gravitation reveals itself in different branches of general relativity. This framework can be useful for general relativity university courses.

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Keywords

gravitational redshift, stationary black holes, synchronous frame

References

- [1] Weinberg S 1972 Gravitation and Cosmology: Principles and Applications of the General Theory of Relativity (New York: Wiley-VCH)
- [2] Harrison E 2000 Cosmology: The Science of the Universe 2nd edn (Cambridge: Cambridge University Press)
- [3] Augousti A T, Gaweczyk M, Siwek A and Radosz A 2012 Touching ghosts: observing free fall from an infalling frame of reference into a Schwarzschild black hole Eur. J. Phys. 33 1-11
- [4] Gaweczyk M, Polonyi J, Radosz A and Siwek A Exchange of signals around the event horizon in Schwarzschild space-time arXiv:1201.4250
- [5] Kassner K 2017 Why ghosts don't touch: a tale of two adventurers falling one after another into a black hole Eur. J. Phys. 38 015605
- [6] Narlikar J V 1994 Spectral shifts in general relativity Am. J. Phys. 62 903
- [7] Synge J 1960 Relativity: The General Theory (North-Holland: Amsterdam)
- [8] Radosz A, Augousti A T and Ostasiewicz K 2009 The Doppler shift in a Schwarzschild spacetime Phys. Lett. A 373 801
- [9] Misner C W, Thorne K S and Wheeler J A 1973 Gravitation (San Francisco: W. H. Freeman and Company)
- [10] Liddle A 2015 An Introduction Into Modern Cosmology 3rd edn (Chichester: Wiley)
- [11] Toporensky A and Zaslavskii O Redshift of a photon emitted along the black hole horizon Eur. Phys. J. C 77 179
- [12] Landau L D and Lifshitz E M 1971 The Classical Theory of Fields (New York: Pergamon Press)
- [13] Martel K and Poisson E 2001 Regular coordinate systems for Schwarzschild and other spherical spacetimes Am. J. Phys. 69 476

- [14] Hamilton A J S and Lisle J P 2008 The river model of black holes *Am. J. Phys.* 76 519
- [15] Radosz A, Augousti A T and Siwek A 2013 On the nature of cosmological redshift and spectral shift in Schwarzschild-like and other spacetimes *Gen. Rel. Grav.* 45 705-15
- [16] Toporensky A and Popov S 2014 The Hubble flow: an observer's perspective *Phys. Usp.* 57 708-13
- [17] Toporensky A and Popov S 2014 *Usp. Fiz. Nauk* 184 767
- [18] Horndeski G 1976 Conservation of charge and the Einstein-Maxwell field equations *J. Math. Phys.* 17 1980
- [19] Frolov V P and Novikov I D 1998 *Physics of Black Holes* (Dordrecht: Kluwer Academic Publishers)
- [20] Davis T M, Lineweaver C H and Webb J K 2003 Solutions to the tethered galaxy problem in an expanding universe and the observation of receding blueshifted objects *Am. J. Phys.* 71 358-64
- [21] Toporensky A V and Popov S B 2015 Cosmological redshift, recession velocities and acceleration measures in FRW cosmologies *Astron. Astrophys. Trans.* 29 65-88
- [22] Tanatarov I V and Zaslavskii O B 2014 What happens to Petrov classification, on horizons of axisymmetric dirty black holes *J. Math. Phys.* 55 022502
- [23] Melia F 2012 Cosmological Redshift in FRW Metrics with Constant Spacetime Curvature *MNRAS* 422 1418